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**DETAILED GRAVIMETRIC GEOID  
CONFIRMATION OF SHORT  
WAVELENGTH FEATURES OF SEA  
SURFACE TOPOGRAPHY DETECTED BY  
THE SKYLAB S-193 ALTIMETER IN THE  
ATLANTIC OCEAN**

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(NASA-TM-X-70905) DETAILED GRAVIMETRIC  
GEOID CONFIRMATION OF SHORT WAVELENGTH  
FEATURES OF SEA SURFACE TOPOGRAPHY DETECTED  
BY THE SKYLAB S-193 ALTIMETER IN THE  
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ABSTRACT

A new detailed gravimetric geoid has been recently computed for the Northwest Atlantic Ocean and Caribbean Sea area in support of the calibration and evaluation of the GEOS-C altimeter. This geoid, computed on a 15' x 15' grid was based upon a combination of surface gravity data with the GSFC GEM-6 satellite derived gravity data. This paper presents a comparison of this new gravimetric geoid with 10 passes of SKYLAB altimeter data. The agreement of the two data types is quite good with the differences generally less than 2 meters. Sea surface manifestations of numerous short wavelength (~100 km) oceanographic features are now indicated in the gravimetric geoid and are also confirmed by the altimetry data.

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## INTRODUCTION

In support of the calibration and evaluation of the GEOS-C altimeter in the Atlantic Ocean off the East Coast of the U.S. , a new detailed gravimetric geoid based upon a combination of satellite derived and surface gravity data has been computed on a 15' x 15' grid (Marsh and Vincent, 1975). Comparison of this new geoid with the detailed geoid previously computed on a 1° x 1° grid (Marsh and Vincent, 1974) revealed height differences as large as 12 meters over the Puerto Rico Trench. Furthermore, differences as large as 3-4 meters were noted in numerous other areas due to the increased resolution of the 15' x 15' surface gravity data.

The accuracy of the 1° x 1° gravimetric geoid was based in part on comparisons with astrogeodetic geoids and dynamically derived satellite tracking station heights. These geodetic comparisons were limited to continental areas and islands and did not provide information on the character of short wavelength (<100km) features in ocean areas. However, with the recent availability of the SKYLAB altimeter data, an independent complementary set of data has been provided for gravimetric geoid computations in ocean areas.

## COMPARISON OF 15' x 15' GRAVIMETRIC GEOID WITH SKYLAB ALTIMETER DATA

Satellite altimetry was performed for the first time during the SKYLAB Mission (1973-1974). During the SL-2, SL-3 and SL-4 missions over 130 sets of data were taken over the oceans, each set being approximately 750 km in length. Extensive evaluations of these data (e.g., pulse shape, radar cross section, time correlation, pulse compression and nadir alignment) have been performed at Wallops Flight Center (McGoogan et al., 1974a, and 1974b). Sea surface topography as measured by the altimeter along the 130 passes has been compared with the GSFC 1° x 1° GEM-6 detailed gravimetric geoid. These comparisons are summarized in McGoogan et al., 1974c. Comparisons for specific passes have also been presented in Marsh and Vincent, 1974b; Vonbun et al., 1975; and Fubara and Mourad, 1974. The relative accuracy ascribed to the altimeter data by McGoogan et al., (1974c) over arcs of 1000 to 2000 km is 1 to 2 meters. Thus as a means of evaluating the relative shape of the new 15' x 15' geoid in the GEOS-C calibration area, comparisons were made with 10 passes of SKYLAB altimeter data.

In addition to altimeter system error and gravimetric geoid error, the effects of orbit error must also be considered in such comparisons. Vonbun et al., (1975), have shown that orbit error for SKYLAB can amount to as much as 5 meters over a well observed revolution. However, orbit error tends to be long wavelength (once per revolution) and thus is generally not significant for relative comparisons over arc lengths of less than 1000 km.

Figure 1 presents a plot of the ground tracks for the passes considered in this study. Figures 2 through 11 present plots of the 15' x 15' gravimetric geoid profiles along these ground tracks superimposed on the altimeter data. Since only a comparison of the relative shapes was of interest, the geoid profiles have been translated along the ordinate axis to provide the best fit to the altimeter data. The agreement of the relative shape of the 15' x 15' geoid and the sea surface topography as derived from the altimeter data is excellent. The differences are generally less than 2 m.

In the evaluation of McGoogan et al., 1974c, short wavelength trends ( $<100$  km) were noted in the altimeter data which were either not visible in the  $1^\circ \times 1^\circ$  gravimetric geoid, for example, the Blake Escarpment, or were only slightly indicated, as was the case in the Puerto Rico Trench area. Short wavelength sea surface topography features which are a manifestation of the bottom topography and subsurface density variations are expected to exhibit amplitudes on the order of a few meters. Therefore these features could be detected by the SKYLAB altimeter system. Thus with the computation of the 15' x 15' gravimetric geoid, the resolution of the geoid has increased to the degree that further analysis of these short wavelength oceanographic features is possible. The locations of numerous such oceanographic features are denoted on the plots.

In Figure 2, four such features are noted. As can be seen in the plot both the altimeter and the gravimetric geoid clearly show the existence of two short wavelength oceanographic features; the Blake Bahama Basin and the Bahama Outer Ridge. Also, the Blake Plateau and the Blake Escarpment are indicated by the altimeter data but are not as pronounced in the gravimetric geoid most likely due to a lack of surface gravity coverage in this particular area.

Figure 3 compares the two data types over the Puerto Rico Trench area. Whereas the  $1^\circ \times 1^\circ$  gravity data only slightly indicated the presence of a sharp depression in the ocean surface, the 15' x 15' geoid and the altimeter geoid map the depression, also both data types indicate the existence of two other oceanographic features namely the Antillean Trench and the Antillean Rise.

Figure 4 presents a pass in the Caribbean slightly to the north of Jamaica. In this plot three features are apparent: the Cayman Trough, a ridge south-east of the trough and an abyssal hill further along the track.



Figure 5 presents another pass in the Caribbean, south of Cuba. Again, the Cayman Trough is apparent as well as the Cayman Ridge and the adjoining abyssal plain. Figure 6 also in the Caribbean shows good agreement between the gravimetric geoid and the altimeter data especially in defining the slope between the abyssal plain and the abyssal hill.

In Figure 7 both the gravimetric geoid and the altimeter data show the rise from the continental slope to the Antillean Ridge. The agreement between the gravimetric geoid and the altimeter data along this profile would have been even better if a slight clockwise rotation had been applied to the gravimetric geoid (or counter clockwise to the altimeter data). This rotation is most likely due to a combination of long wavelength errors in the gravimetric geoid and orbit errors.

Figures 8 and 9 are in the Antillean Islands area. In Figure 8 the Antilles Outer Ridge, the Puerto Rico Trench and Antillean Volcanic arc are depicted by the altimeter as well as the gravimetric geoid data. The agreement between the gravimetric geoid and the altimeter data on this pass is generally good in spite of the high noise level along certain portions of the pass. Of particular significance is the good agreement over the Puerto Rico Trench. This is in contrast to the portion of the Puerto Rico Trench noted in Figure 3 where the gravimetric geoid and the altimeter data varied in the definition of the deep part of the trench. This variation in Figure 3 is attributed to the steep gradient of the trench over a small area (approximately 60 km) which is beyond the existing resolution of the gravimetric geoid versus the gradual depression noted in Figure 8 where the gradient extends over a distance of approximately 150 km, well within the resolution of the gravimetric geoid. In Figure 9 the gravimetric geoid and the altimeter geoid show the sharp variation in slope between the abyssal plain and the Antillean Ridge.

Figure 10 shows a pass between Washington and Bermuda. The continental shelf, the continental slope, and the Hatteras Abyssal Plain are defined. Also the altimeter geoid shows the Hatteras Outer Ridge as well as the Bermuda Rise. Figure 11 represents a pass parallel to the one shown in Figure 10. This figure illustrates the excellent agreement of the gravimetric geoid with the altimeter data over a distance of about 1000 km. Although short wavelength structure is noted in this figure, the features are smaller in amplitude and less obvious than in the previous figures. This profile is of additional interest since it provides information on the relative accuracy ( $\pm 2$  m) of the geoid in the vicinity of the Wallops and Bermuda tracking stations.

## SUMMARY AND CONCLUSIONS

The resolution and precision of the 15' x 15' gravimetric geoid has been sufficient to provide additional confirmation of the detection of short wave sea surface topography features by the SKYLAB altimeter system. Numerous trends in the SKYLAB data that may have been previously attributed to errors in the system, for example, noise, pointing error or mode changes now appear to be accurate representations of physical features.

Preliminary analysis of crustal sections derived from geophysical data in the vicinity of several of these passes have produced short wavelength signatures similar to those exhibited by the altimeter data. Homogeneous geophysical data particularly over the oceans is lacking on a global basis. Thus, satellite altimetry being inherently homogeneous is expected to play a major role in the definition of crustal structure and subsequent plate tectonic studies.

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**FIGURE 1 LOCATION OF SKYLAB PASSES USED IN GRAVIMETRIC GEOID COMPARISONS**

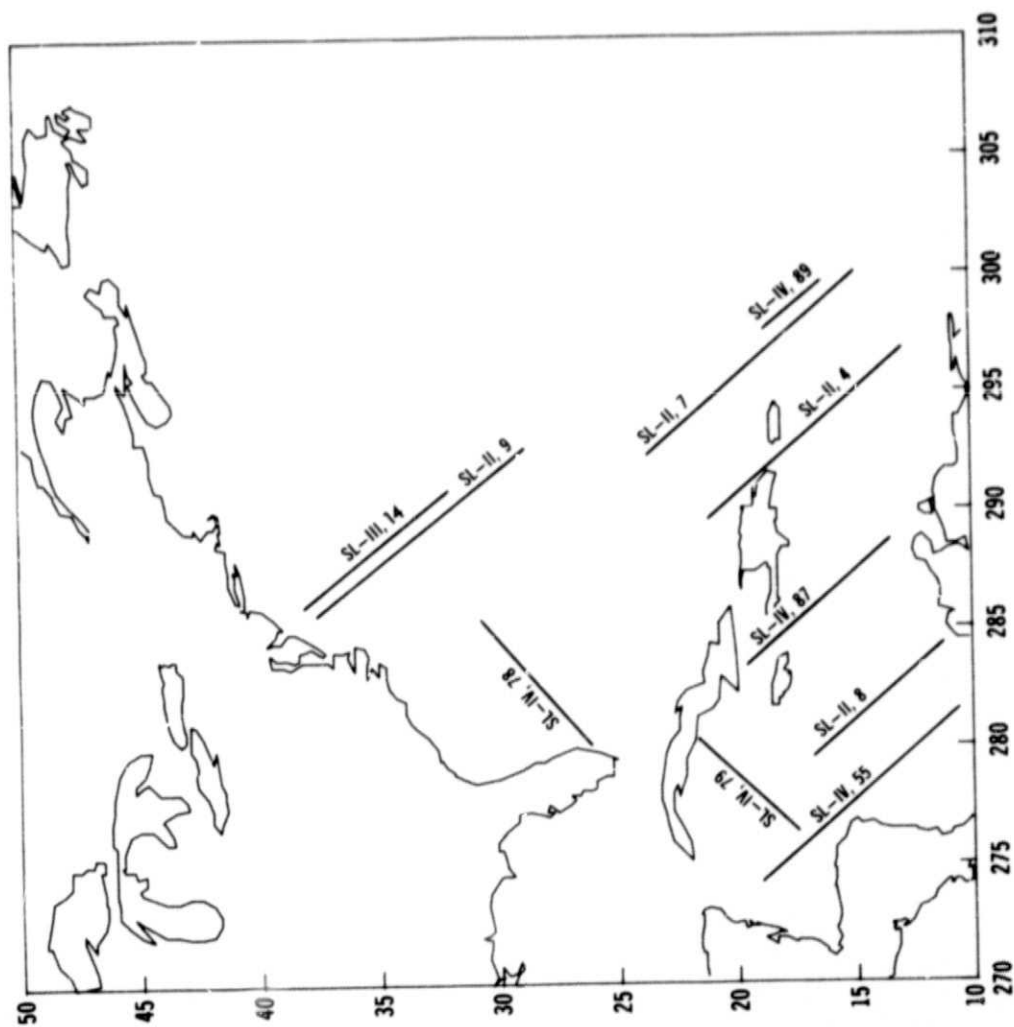
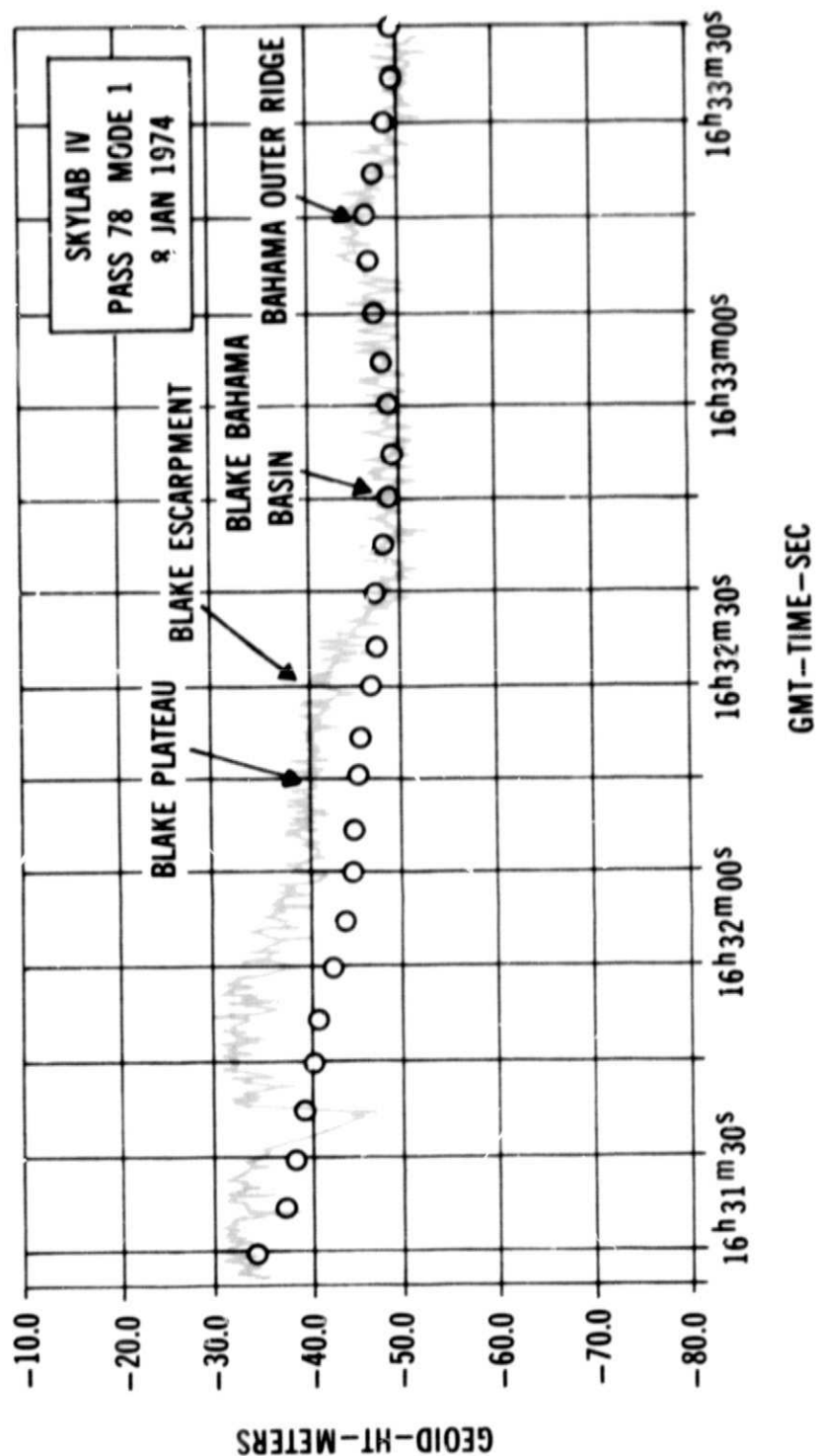


FIGURE 2 COMPARISON OF 15' X 15' GRAVIMETRIC GEOID AND THE SKYLAB  
ALTIMETER DATA OVER THE BLAKE ESCARPMENT AREA

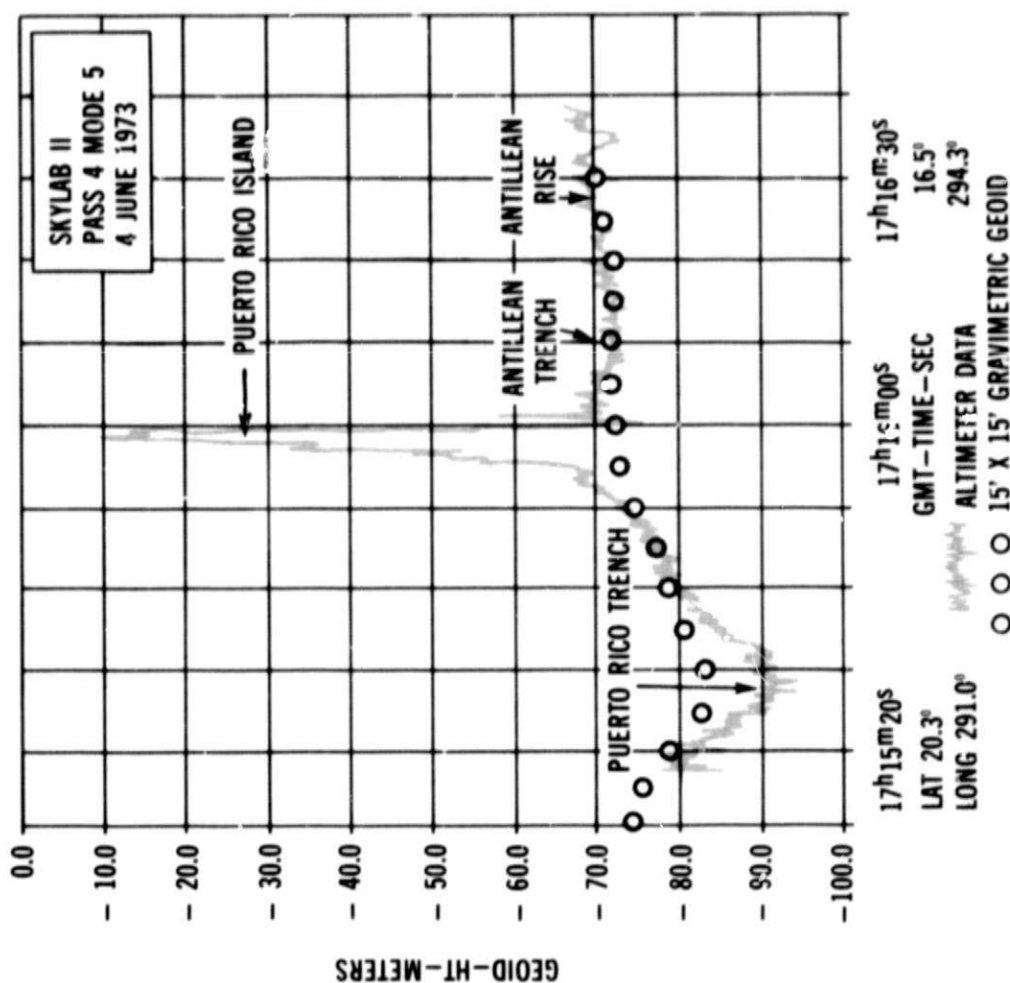


LAT 20.0°  
LONG 280.1°

ALTIMETER DATA  
O O O 15' X 15' GRAVIMETRIC GEOID

31.3°  
286.1°

FIGURE 3 COMPARISON OF THE 15' X 15' GRAVIMETRIC GEOID AND THE SKYLAB II  
ALTIMETER DATA OVER THE PUERTO RICAN TRENCH AREA



**FIGURE 4 COMPARISON OF THE 15' X 15' GRAVIMETRIC GEOID AND THE  
SKYLAB ALTIMETER DATA NORTH OF JAMAICA**

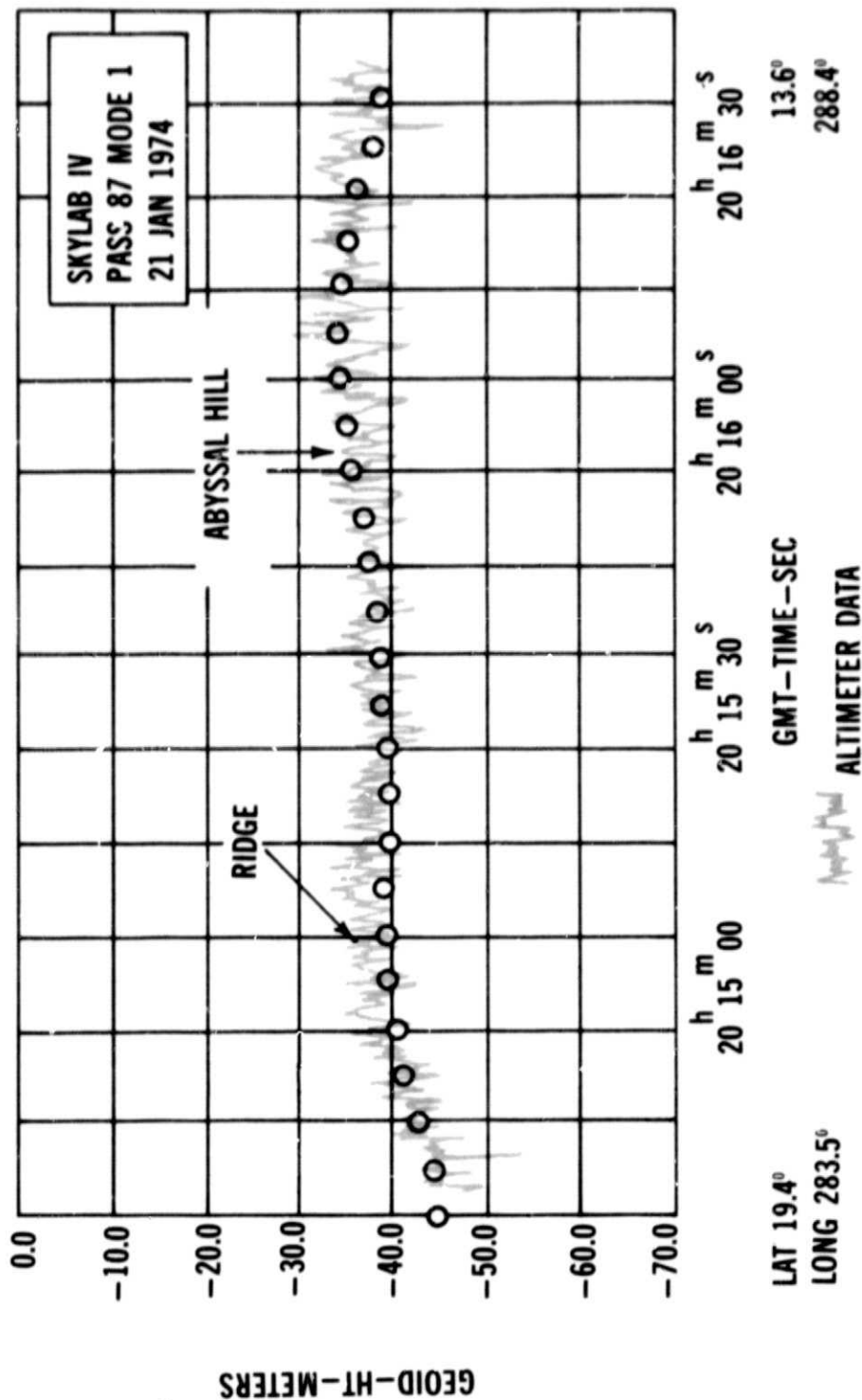


FIGURE 5 COMPARISON OF THE 15' X 15' GRAVIMETRIC GEOID AND THE  
SKYLAB ALTIMETER DATA SOUTH OF CUBA

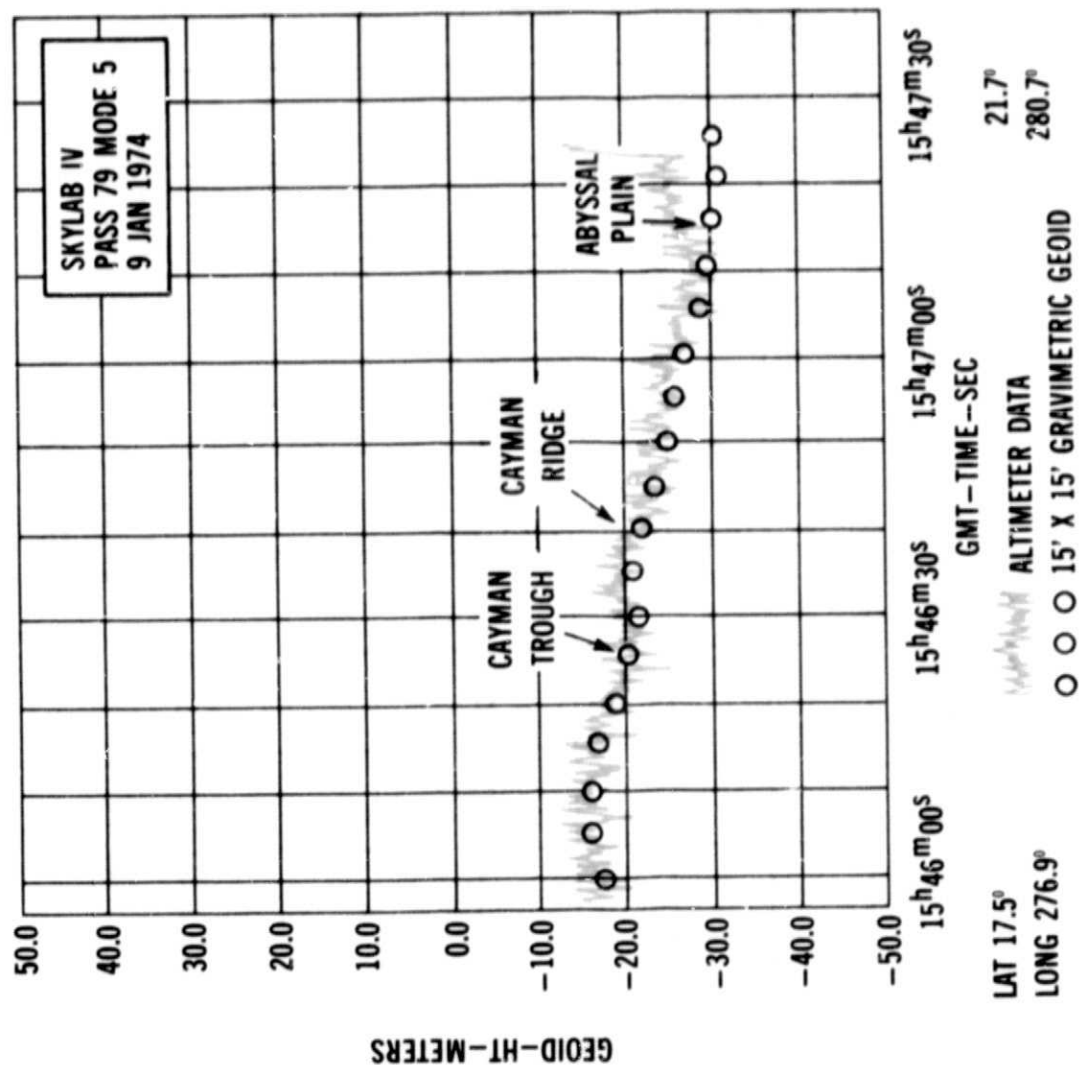




FIGURE 6 COMPARISON OF THE 15' X 15' GRAVIMETRIC GEOID AND THE  
SKYLAB ALTIMETER DATA IN THE CARIBBEAN

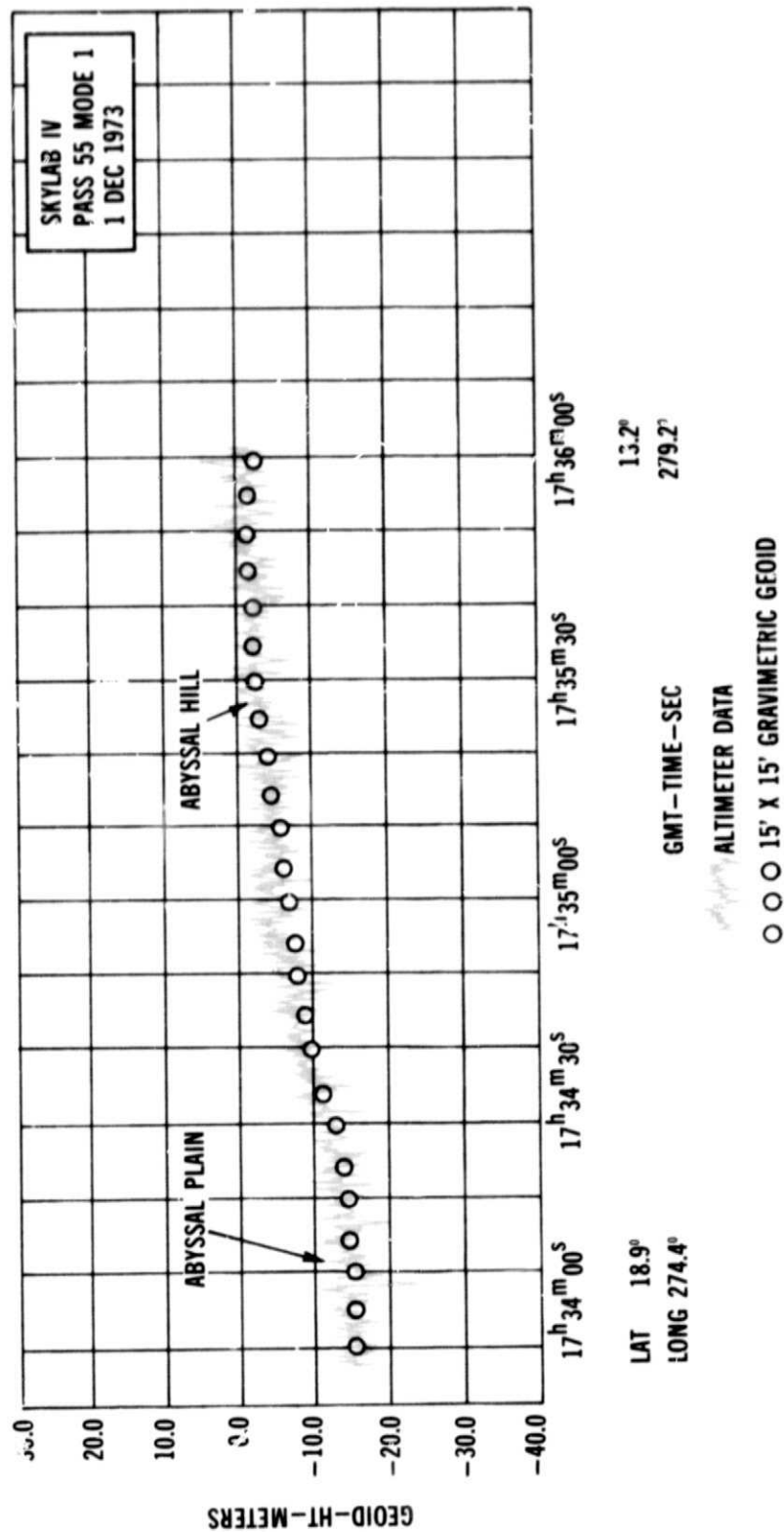


FIGURE 7 COMPARISON OF THE 15' X 15' GRAVIMETRIC GEOID AND THE  
SKYLAB ALTIMETER DATA IN THE CARIBBEAN

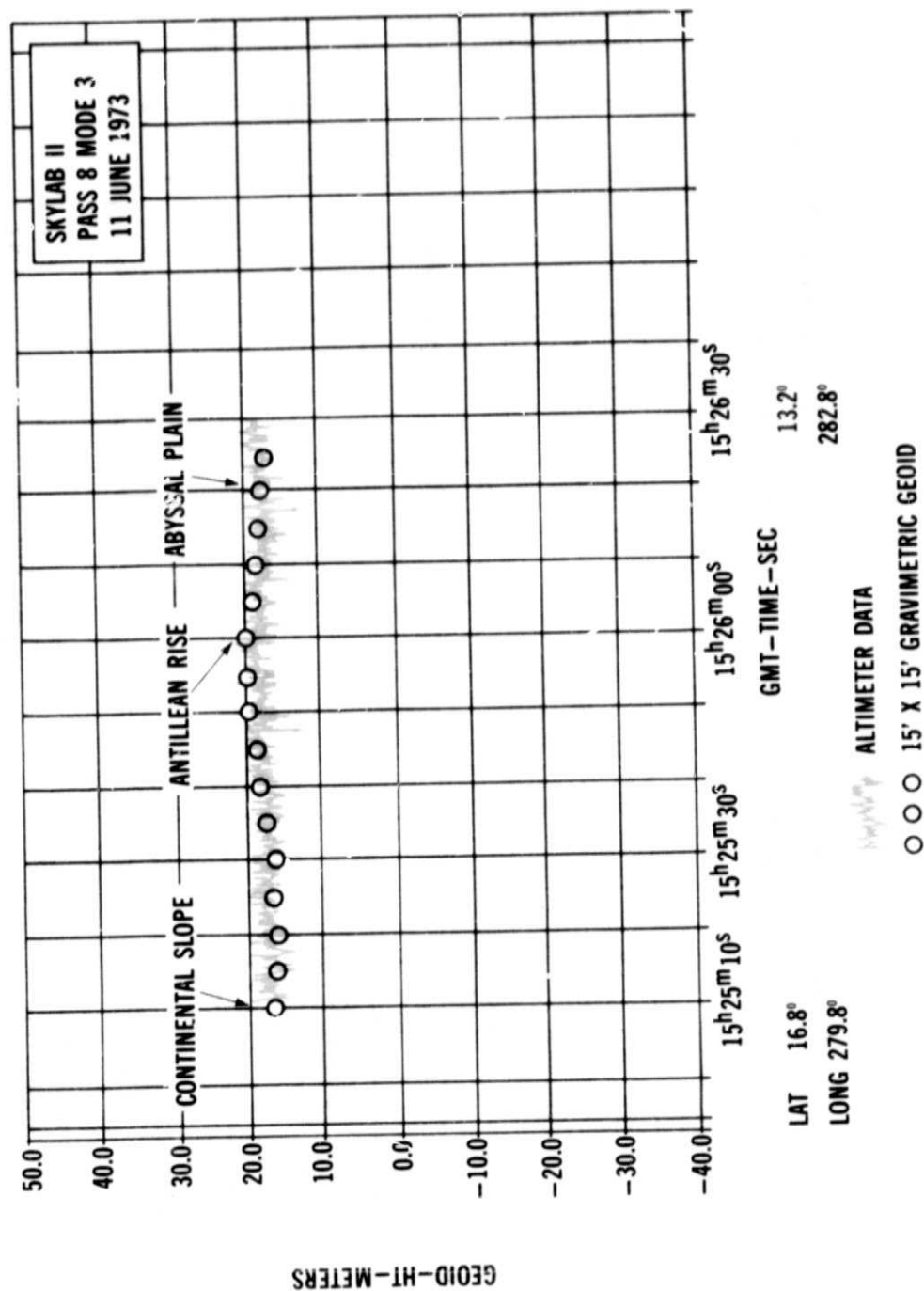
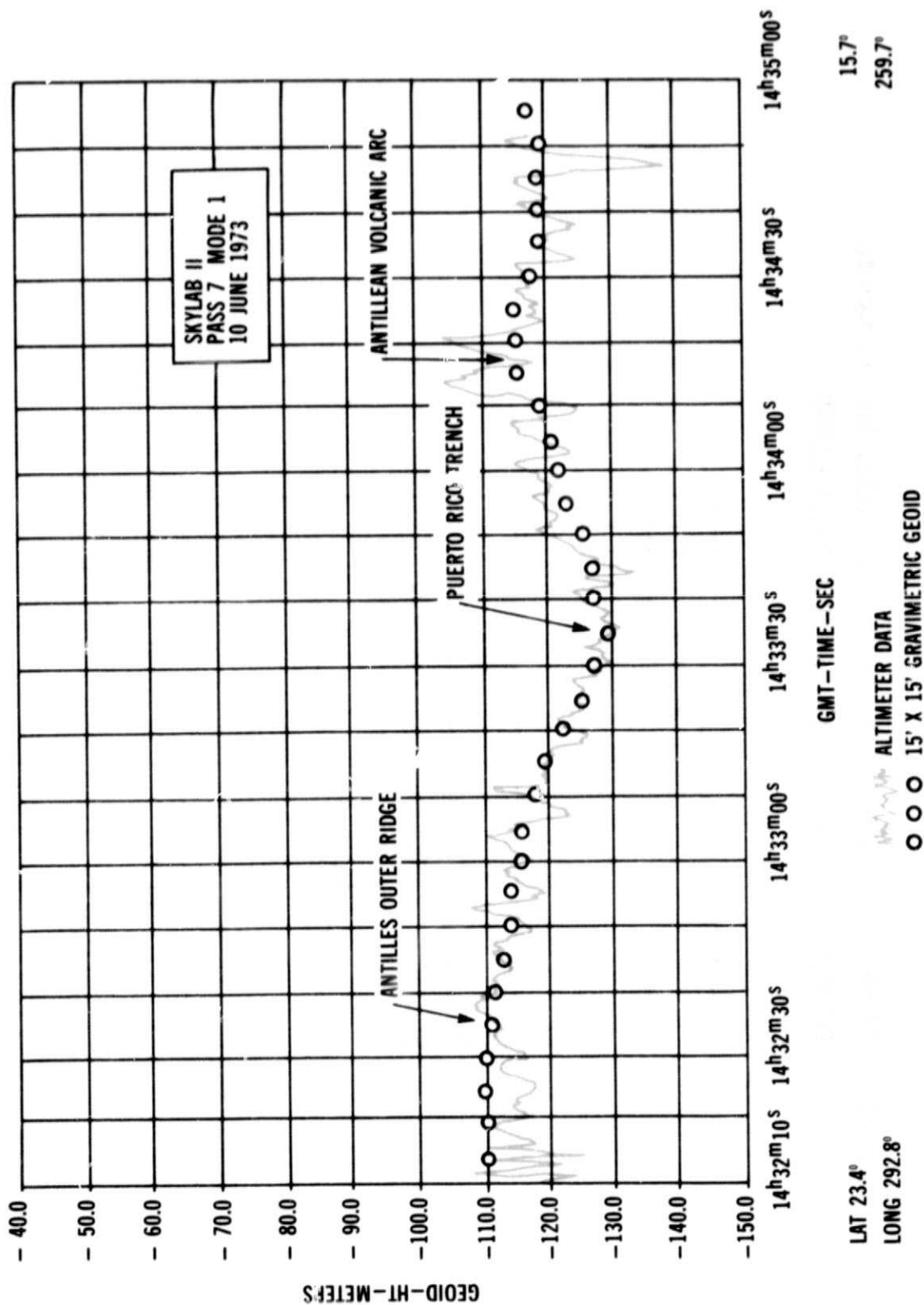


FIGURE 8 COMPARISON OF THE 15' X 15' GRAVIMETRIC GEOID AND THE SKYLAB  
ALTIMETER DATA NORTH EAST OF PUERTO RICO



**FIGURE 9 COMPARISON OF THE 15' X 15' GRAVIMETRIC GEOID AND THE SKYLAB  
ALTIMETER DATA NORTH EAST OF THE ANTILLES ISLANDS**

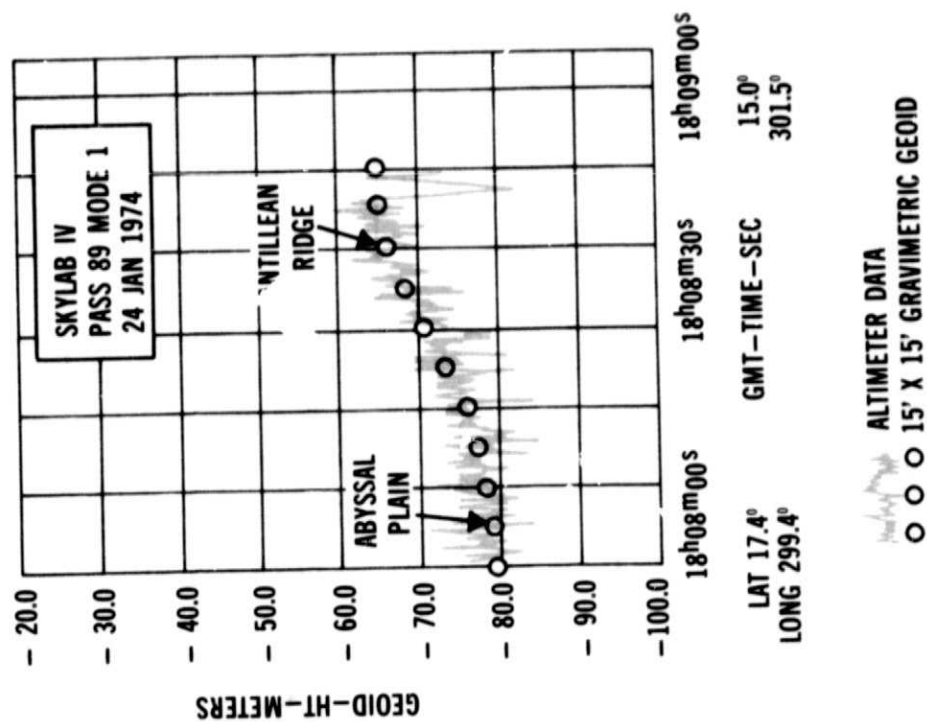


FIGURE 10 COMPARISON OF THE 15' X 15' GRAVIMETRIC GEOID AND THE SKYLAB  
ALTIMETER DATA IN ATLANTIC BETWEEN WASHINGTON AND BERMUDA

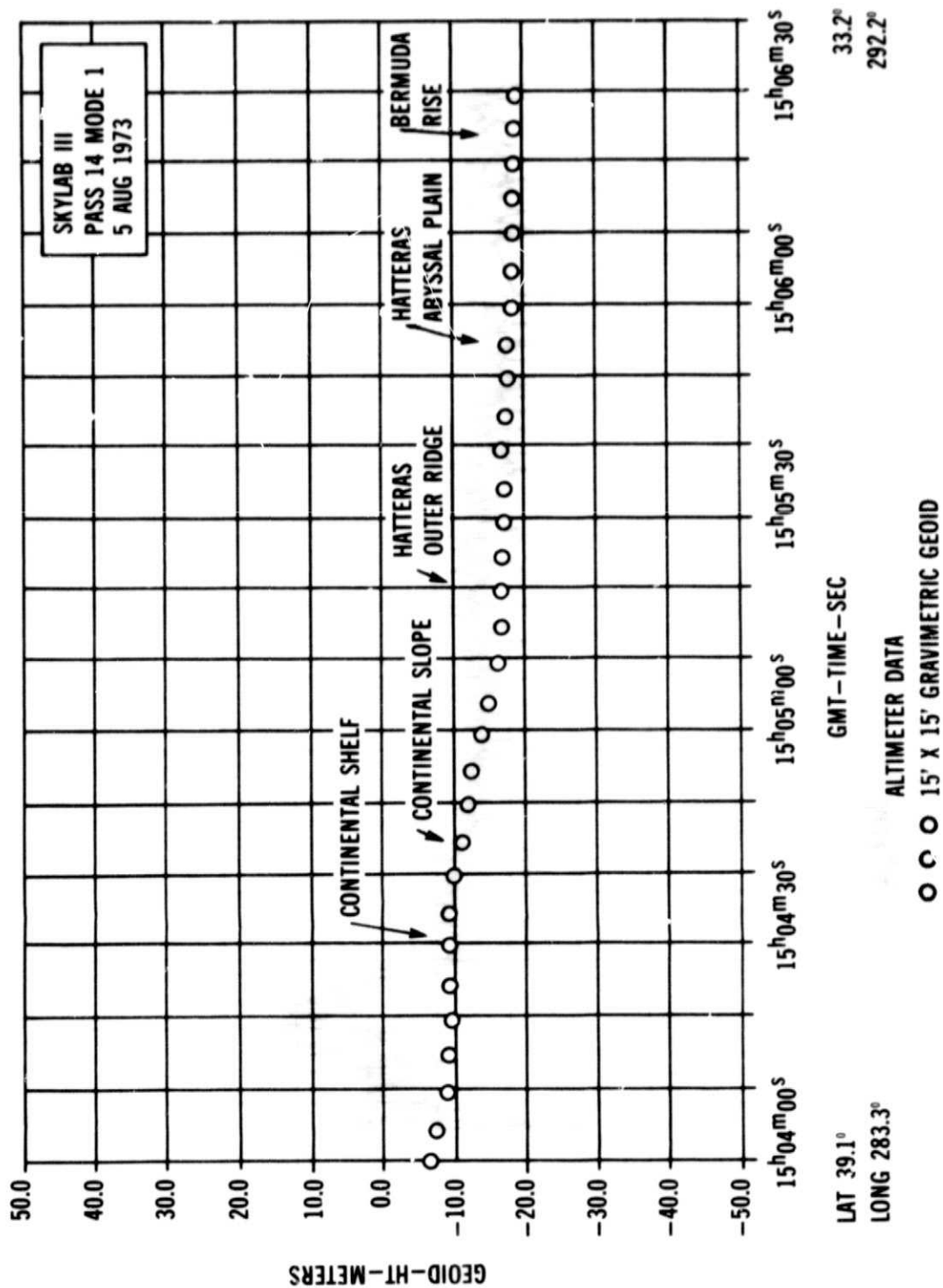


FIGURE 11 COMPARISON OF THE 15' X 15' GRAVIMETRIC GEOID AND THE  
SKYLAB ALTIMETER DATA IN THE ATLANTIC

